

WHAT IS CLAIMED IS:

1. Within a method of making an optical interference filter having thin layers of alternately high and low indices of refraction, a method of determining layer thicknesses, said
5 method comprising the steps of:

(a) providing sample spectra and measurements of a predetermined characteristic associated with respective said sample spectra;

(b) selecting an initial number of said layers;

(c) selecting a thickness for each layer of said number of layers;

(d) determining a transmission spectrum of an optical filter having said number of layers and said selected thickness of each said layer;

(e) defining a first regression formula that relates an interaction of light with said transmission spectrum to a regression value;

(f) applying each said sample spectrum to said regression formula, thereby determining said regression value for each said
20 sample spectrum;

(g) defining a comparison relationship between said regression values and said measurements; and

(h) optimizing said comparison relationship for said regression values, wherein thickness of each said layer is an optimization variable.

2. The method as in claim 1, wherein said regression formula includes the difference between said light transmitted by said transmission spectrum and said light reflected by said transmission spectrum.

3. The method as in claim 2, wherein said regression formula is defined as $Y = a_0 + G(2T-1) \cdot S$, wherein Y is said regression value, a_0 is an offset value, G is a gain value, T is said transmission spectrum, and S is the spectrum of said light, and wherein said offset value and said gain value are optimization variables in said optimizing step.

4. The method as in claim 1, wherein said comparison relationship includes an average of the differences between said measurement and said regression value for each said sample spectrum.

5. The method as in claim 4, wherein said comparison relationship includes a root mean square of said differences.

6. The method as in claim 1, wherein said optimizing step includes a quasi-Newton optimization.

7. The method as in claim 1, including
defining a tolerance level for said comparison relationship,

comparing said comparison relationship optimized at step

5 (h) with said tolerance level, and

where said optimized comparison relationship is beyond said tolerance level, repeatedly increasing said initial number of layers and executing steps (c) - (h) until said optimized comparison relationship falls within said tolerance.

8. The method as in claim 1, wherein said optimizing step includes eliminating any said layer for which said thickness falls below a predetermined level during optimization.

9. The method as in claim 8, including
selecting a plurality of sets of initial conditions at steps (b) and (c), wherein each said set includes a selection of a number of layers and respective layer thicknesses,
executing steps (d) - (h) for each said set, and
selecting a group of layer thicknesses associated with said comparison relationship optimized at step (h) for one of said sets.

10. The method as in claim 1, including
determining a second regression formula that relates said sample spectra to said measurements,

defining a comparison relationship between said first
5 regression formula and said second regression formula,

optimizing said last-mentioned comparison relationship for
said regression formula, wherein thickness of each said layer is
an optimization variable,

replacing said thicknesses selected at step (c) with
10 thicknesses optimized in said last-mentioned optimizing step and
re-defining said first regression formula based on thicknesses
associated with said comparison relationship optimized at said
last-mentioned optimizing step, and

executing steps (f) - (h) based on said replaced
15 thicknesses and said re-defined first regression formula.

11. The method as in claim 1, including

(i) forming an optical filter segment comprising a first
layer of said optical filter, based on a thickness for said
first layer determined at step (h),

(j) determining an actual thickness of said first layer
formed at step (i),

(k) where said actual thickness is less than a desired
thickness of said first layer, adding a thickness to said first
layer based on the difference between said actual thickness and
10 said desired thickness.

12. The method as in claim 1, including

(i) forming an optical filter segment comprising a first
layer of said optical filter, based on a thickness for said
first layer determined at step (h),

5 (j) measuring a transmission spectrum of said filter
segment,
(k) determining an actual thickness of said first layer
based on said transmission spectrum determined at step (j),
(l) comparing said actual thickness to a desired thickness
10 of said first layer,
(m) where said actual thickness is less than said desired
thickness, adding a thickness to said first layer based on the
difference between said actual thickness and said desired
thickness.

13. The method as in claim 12, wherein said desired
thickness is said thickness for said first layer determined at
step (h).

14. The method as in claim 13, including, following step
(m), comparing said difference to a predetermined threshold and
repeatedly executing steps (j) - (m) until said difference falls
below said threshold.

15. The method as in claim 13, including, following step
(m), the step (n) repeating steps (b) - (h), including
selecting a thickness of said first layer resulting from
step (m) as said thickness for said first layer at the repeated
5 step (c), and

excluding thickness of said first layer as an optimization
variable at the repeated step (h).

16. The method as in claim 15, including, following step (o), repeating steps (i) - (n) for successive layers of said optical filter, wherein each repeated step (i) includes forming each said successive layer on the previous said layer.

17. The method as in claim 13, wherein step (i) includes forming said first layer to a predetermined target thickness based on said thickness determined at step (h), and wherein step (k) includes

5 determining a target transmission spectrum of said optical filter segment, said target spectrum being a transmission spectrum that would be expected if said first layer were of said target thickness,

10 defining a comparison relationship between said transmission spectrum measured at step (j) and said target transmission spectrum, and

15 optimizing said last-mentioned comparison relationship for said target spectrum, wherein thickness of said first layer is an optimization variable.

18. The method as in claim 11, including, following step (k), the step (l) repeating steps (b) - (h), including

20 selecting a thickness of said first layer resulting from step (k) as said thickness for said first layer at the repeated
5 step (c), and

excluding thickness of said first layer as an optimization variable at the repeated step (h).

19. The method as in claim 18, including, following step (l), repeating steps (i) - (l) for successive layers of said optical filter, wherein each repeated step (i) includes forming each said successive layer on the previous said layer.

20. Within a method of making an optical interference filter having thin layers of alternately high and low indices of refraction disposed on a substrate, a method of determining layer thicknesses, said method comprising the steps of:

(a) providing sample spectra and measurements of a predetermined characteristic associated with respective said sample spectra;

(b) selecting a substrate;

(c) selecting an initial number of said layers;

(d) selecting a material with which to make each layer of said number of layers;

(e) selecting a thickness for each layer of said number of layers;

(f) determining a transmission spectrum of an optical transmission filter having said substrate and having said number of layers, wherein each said layer is made of said material selected for said layer at step (d) and has said thickness selected for said layer at step (e);

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20 (g) defining a first regression formula that relates an
interaction of light with said transmission spectrum determined
at step (f) to a regression value;

(h) applying each said sample spectrum to said first
regression formula, thereby determining said regression value
for each said sample spectrum;

25 (i) defining a comparison relationship between said
regression values and said measurements, wherein said comparison
relationship defines a comparison value; and

30 (j) optimizing said comparison relationship for said
regression values to a minimum said comparison value, wherein
thickness of each said layer is an optimization variable.

21. The method as in claim 20, including

35 selecting a plurality of sets of initial conditions at
steps (b), (c) and (d), wherein each said set includes a
selection of a substrate, an initial number of said layers and
5 respective thicknesses, and a material with which to make each
said layer,

executing steps (e) - (j) for each said set, and

10 selecting a group of layer thicknesses associated with said
comparison relationship optimized at step (j) for one of said
sets,

wherein said optimizing step includes eliminating any said layer for which said thickness falls below a predetermined level during optimization.

22. The method as in claim 20, including

determining a second regression formula that relates said sample spectra to said measurements,

defining a comparison relationship between said first regression formula and said second regression formula,

optimizing said last-mentioned comparison relationship for said first regression formula, wherein thickness of each said layer is an optimization variable,

replacing said thicknesses selected at step (e) with thicknesses optimized in said last-mentioned optimizing step and re-defining said first regression formula based on thicknesses associated with said comparison relationship optimized at said last-mentioned optimizing step, and

executing steps (h) - (j) based on said replaced thicknesses and said re-defined first regression formula.

23. The method as in claim 20, including

(k) forming an optical filter segment comprising a first layer of said optical filter, based on a thickness for said first layer determined at step (j),

(l) measuring a transmission spectrum of said filter segment,

(m) determining an actual thickness of said first layer based on said transmission spectrum determined at set (l),

(n) comparing said actual thickness to a desired thickness of said first layer, said desired thickness being said thickness for said first layer determined at step (j),

(o) where said actual thickness is less than said desired thickness, adding a thickness to said first layer based on the difference between said actual thickness and said desired thickness.

24. Within a method of making an optical interference filter having thin layers of alternately high and low indices of refraction disposed on a substrate, a method of determining layer thicknesses, said method comprising the steps of:

(a) providing sample spectra and measurements of a predetermined characteristic associated with respective said sample spectra;

(b) selecting a substrate;

(c) selecting an initial number of said layers;

(d) selecting a material with which to make each layer of said number of layers;

(e) selecting a thickness for each layer of said number of layers;

(f) determining a transmission spectrum of an optical transmission filter having said substrate and having said number

of layers, wherein each said layer is made of said material selected for said layer at step (d) and has said thickness selected for said layer at step (e);

(g) defining a regression formula that relates an
20 interaction of light with said transmission spectrum determined at step (f) to a regression value;

(h) applying each said sample spectrum to said regression formula, thereby determining said regression value for each said sample spectrum;

(i) defining a comparison relationship between said
25 regression values and said measurements, wherein said comparison relationship defines a comparison value;

(j) optimizing said comparison relationship for said
30 regression values to a minimum said comparison value, wherein thickness of each said layer is an optimization variable;

(k) forming an optical filter segment comprising a first layer of said optical filter, based on a thickness for said first layer determined at step (j),

(l) measuring a transmission spectrum of said filter
35 segment;

(m) determining an actual thickness of said first layer based on said transmission spectrum determined at step (l);

(n) comparing said actual thickness to a desired thickness of said first layer, said desired thickness being said thickness
40 for said first layer determined at step (j);

(o) where said actual thickness is less than said desired thickness, and where the difference between said actual thickness and said desired thickness is greater than a predetermined threshold, adding a thickness to said first layer
45 of one-half said difference;

(p) following step (o), repeatedly executing steps (l) -
(o) until said difference falls below said threshold;

(q) following step (p), repeating steps (b) - (j),
including

50 selecting a thickness of said first layer resulting from step (p) as said thickness for said first layer at the repeated step (e), and

excluding thickness of said first layer as an optimization variable at step (j); and

55 (r) following step (q), repeating steps (k) - (q) for successive layers of said optical filter, wherein each repeated step (k) includes forming each said successive layer on the previous said layer.